

Rotor Flapping Response to Active Control

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Rotor active control using higher harmonic blade pitch has been proposed as a means to reduce both rotor radiated noise and airframe vibration and to enhance rotor performance. The higher harmonic input, however, can affect rotor thrust and cyclic flapping – the basic trim characteristics of the rotor. Some of the trim changes can negate the active control benefits. For example, wind tunnel test results of a full scale BO-105 rotor with individual-blade control indicate some rotor performance improvements, accompanied with changes in rotor trim, using two-per-rev blade pitch input [1]. The observed performance benefits could therefore be a simple manifestation of the trim change rather than an efficient redistribution of the rotor airloads. More recently, the flight test of the BO-105 helicopter equipped with individual-blade-control actuators also reported trim changes whenever the two-per-rev blade pitch for noise reduction was activated [2]. The pilot had to adjust the trim control to maintain the aircraft under a constant flight path. These two cases highlight the importance of trim considerations in the application of active control to rotorcraft.

Test results of the three-bladed XV-15 rotor in the 80- by 120-Foot Wind Tunnel [3] also show that the blade cyclic flapping response is sensitive to the two-per-rev blade pitch input. The flapping response shown in the figure was obtained from a two-per-rev phase sweep with 1.4 deg amplitude in a simulated descent condition. During the phase sweep, the trim control input was fixed. The longitudinal flapping response to the two-per-rev blade pitch input is quite significant, 1 deg of this active control component producing almost half a degree of longitudinal flapping. Also shown in the figure, the CAMRAD II computations with a free wake inflow model over predict the sensitivity of longitudinal flapping response to the two-per-rev input. Both test data and analysis indicate a smaller sensitivity of the lateral blade flapping response to the two-per-rev blade pitch input than the longitudinal response.

In an effort to enhance understanding of the rotor trim response to higher harmonic blade pitch, the paper aims to explore the phenomena under an analytical framework. CAMRAD II will first be validated using wind tunnel test data from the XV-15 rotor. The analysis will then be extended to predict the UH-60 rotor flapping response to higher harmonic blade pitch. These results will assist in planning for the individual-blade control test of the full-scale UH-60A rotor in the 80- by 120-Foot Wind Tunnel.

References

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3. Nguyen, K., Betzina, M., Kitaplioglu, C., "Full-Scale Demonstration of Higher Harmonic Control for Noise and Vibration Reduction on the XV-15 Rotor," Proceedings of the 56th American Helicopter Society Annual Forum, Virginia Beach, VA, May 2000.

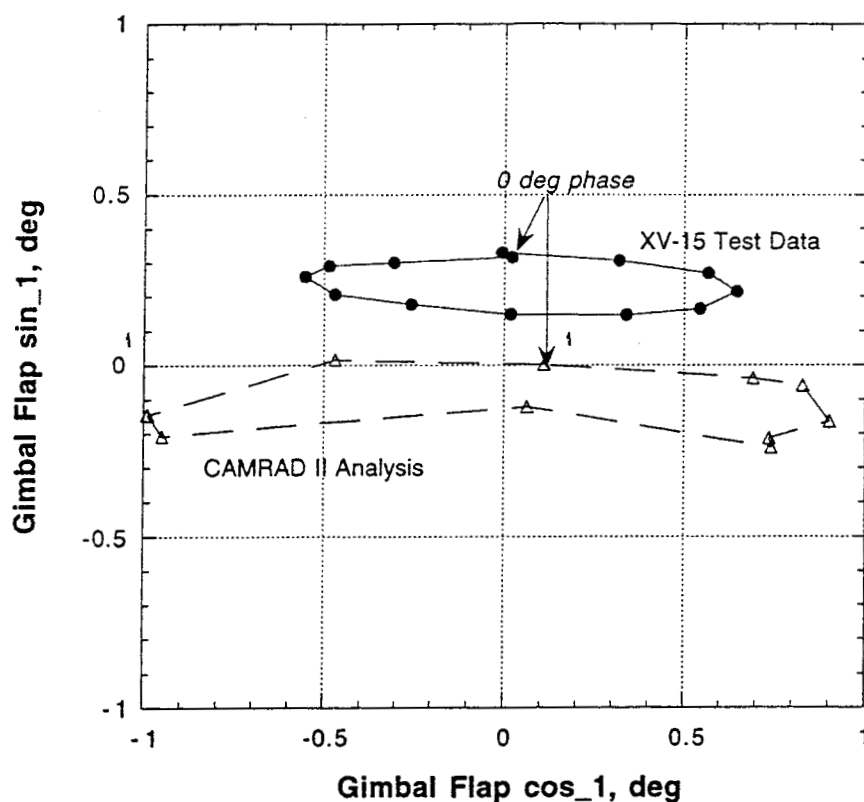


Figure. Blade root flapping response to 1.4 deg of two-per-rev phase sweep, $\mu = 0.15$, $C_T/\sigma = 0.09$, 3 deg shaft tilt aft.

Abstract

The paper presents analytical results of the rotor flapping responses to the higher harmonic blade pitch. The analysis will be conducted using the CAMRAD II rotorcraft analysis and will be validated with the XV-15 wind tunnel test data. The analysis also includes the responses of the UH-60A rotor to the active control, and the results will help in the planning of the individual-blade control test of the full scale rotor in the 30- by 120-Foot Wind Tunnel.

The paper will be presented at the American Helicopter Society Northeast Region Active Control Technology Conference, October 4-5, 2000 in Fairfield County, Connecticut.